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RESEARCH MEMORANDUM

COMPARISON OF LIFT-CURVE SLOPES FOR A MODEL TESTED IN TWO SLOTTED TUNNELS OF DIFFERENT SIZES AT HIGH SUBSONIC SPEEDS

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

The boundary effects on an 18-inch span, 60° triangular wing model tested in the 26-inch Langley transonic blowdown tunnel are shown to cause only small decreases in the lift-curve slopes from those obtained with the same model in the Langley 8-foot transonic tunnel; the decreases amount to less than 0.001 per degree and 0.003 per degree at Mach numbers of 0.80 and 0.975, respectively. The theory of a previously published paper (NACA RM L53A26), although not exactly applicable to the present case, gave corrections to the lift-curve slopes obtained in the smaller tunnel which appeared to be of the correct sign and of the proper order of magnitude.

INTRODUCTION

In recent years, a number of tunnels utilizing longitudinal slots in the otherwise closed walls have been constructed at the Langley Laboratory and elsewhere. Since slotted tunnels may be operated continuously from subsonic to supersonic Mach numbers without change in tunnel configuration, they have proved to be an important source of data for the transonic regime.

The various types of boundary interferences that occur in slotted tunnels have naturally received some attention. In regard to boundary-induced-angle interference, theoretical studies are presented in references 1 and 2. In reference 1 the effects of span, span loading, slot configuration, and tunnel cross-sectional shape for subsonic Mach numbers are considered. In reference 2 a homogeneous boundary is substituted for the discrete slots considered in reference 1; the boundary-induced angles calculated by reference 2 are almost identical to the values calculated by reference 1 for tunnels containing as few as four

slots. Experimental studies of boundary-induced-angle effects are contained in references 3 and 4.

In the present report additional experimental data on boundary-induced-angle effects are presented and some aspects of the theory of reference 1 are verified. The data consist of lift-curve slopes obtained at high subsonic speeds with a 60° triangular wing model in the Langley transonic blowdown tunnel. These data are compared with similar data (ref. 5) obtained with the same model in the Langley 8-foot transonic tunnel.

SYMBOLS

b	ratio of wing span to tunnel diameter
$\bar{c}$	mean aerodynamic chord
C_L	lift coefficient, L/qS
C_{L_α}	lift-curve slope, $dC_L/d\alpha$
d_{max}	maximum fuselage diameter
l	extended fuselage length
L	lift
M	Mach number
q	free-stream dynamic pressure
r	fuselage radius
R	ratio of open periphery to total periphery of tunnel cross section
S	total area of wing
x	distance from fuselage nose
α	angle of attack, deg

MODEL

The model used for the present tests in the Langley transonic blowdown tunnel and for the tests of reference 5 made in the Langley 8-foot transonic tunnel consisted of a 60° triangular wing mounted on a pointed fuselage. The wing had a span of 18.24 inches and NACA 65A002 airfoil sections parallel to the plane of symmetry. A sketch of the model is presented in figure 1 and the ordinates of the fuselage are given in figure 2. Both wing and fuselage were constructed of steel. The same sting balance was used for the tests in both tunnels.

TUNNELS

The Langley transonic blowdown tunnel is an octagonal, slotted throat tunnel with slots located in each corner. The slot configuration used for the present tests was an experimental one and consisted of slots which had a ratio of open to total periphery of the tunnel cross section which varied from 0.034 at the nose of the model to 0.104 at the end of the fuselage as shown in figure 3. Calibration tests with this slot configuration indicated that the Mach number variation along the tunnel center line at subsonic speeds, with the model removed, were no greater than ±0.005 in the region occupied by the model. In the test section, opposite walls are 2.21 feet apart and the cross-sectional area is 4.04 square feet.

The Langley 8-foot transonic tunnel is a dodecagonal single-return tunnel with slots located in each corner. The ratio of open to total periphery was approximately 0.111 along the model length. The test section area is about 42.87 square feet. The tunnel is described in more detail in reference 6.

TESTS

An angle-of-attack range of from approximately -4° to 4° was covered for each nominal Mach number in the transonic blowdown tunnel tests while the stagnation pressure was maintained essentially constant. An appreciable variation of Mach number with angle of attack occurred during each run because of reduced tunnel efficiency at the higher angles of attack. However, data were obtained at a sufficient number of Mach numbers so that by cross fairing the data the variations of lift coefficient with angle of attack were obtained for constant Mach numbers. The Mach number was changed by changing the stagnation pressure. For the Mach number range from 0.79 to 1.09, the stagnation pressure ranged from

1.1 to 1.2 atmospheres; these ranges of Mach number and stagnation pressure corresponded to a Reynolds number range of from 4.4×10^6 to 5.5×10^6 based on the mean aerodynamic chord. A sting-position indicator was used to measure the nominal angles of attack. The angles so obtained were corrected for sting deflection and wing twist to obtain the corrected angles of attack. The correction to the nominal angle of attack for $\alpha = 4^\circ$ and $M = 1.0$ was 0.15°; all of the corrections, which were determined from static measurements, were in the direction to increase the absolute values of the angles of attack. The accuracy of the corrected angles is believed to be within $\pm 0.1^\circ$.

In the 8-foot transonic tunnel tests, the Mach number was varied during each run while a constant angle of attack was maintained. The angle of attack of the model was measured with an optical system sighted on a reference line on the fuselage and is estimated to be accurate within $\pm 0.1^\circ$. The angle-of-attack range covered in the tests was from 0° to 7° and the Mach number range, from 0.60 to 1.125. The tunnel operates at essentially atmospheric stagnation pressure and the Reynolds number varied from approximately 2.9×10^6 to 3.5×10^6. The 8-foot transonic tunnel data contained herein were obtained from reference 5.

RESULTS

Experimental data.- A typical variation of Mach number and lift coefficient with angle of attack (with the stagnation pressure held essentially constant) during one test in the transonic blowdown tunnel is shown in figure 4 for $M \approx 0.9$. Cross plots of data similar to that in figure 4 yielded the variation of lift coefficient with angle of attack at various Mach numbers shown in figure 5. The variation of lift-curve slope with Mach number for the tests in the transonic blowdown tunnel and the 8-foot transonic tunnel, obtained from figure 5 and reference 5, respectively, are presented in figure 6.

The C_{L_α} curve from the transonic blowdown tunnel tests is shown (fig. 6) to be only slightly lower than that from the 8-foot transonic tunnel tests in spite of the rather large difference in dimensions of the two tunnels. (The value of b, ratio of wing span to tunnel diameter, for the tests in the transonic blowdown tunnel was 0.670 and in the 8-foot transonic tunnel, 0.206.) The differences in lift-curve slope amount to less than 0.001 per degree and 0.003 per degree at Mach numbers of 0.80 and 0.975, respectively; the small value of b in the 8-foot transonic tunnel tests suggest that the boundary interference on the data obtained therein would be small so that the small difference in lift-curve slopes could be attributed almost entirely to the boundary

interference in the transonic blowdown tunnel. In order to provide a basis for comparison, the boundary-induced-angle correction calculated from Glauert's simple formula for the model of the present investigation mounted in a closed 26-inch-diameter circular tunnel yields a lift-curve-slope correction of -0.005 per degree.

Theoretical corrections.- The theory of reference 1, which concerns the lift interference of the boundaries, is based on the assumption of a constant value of R (ratio of open periphery to total periphery) throughout the test section. This assumption is satisfied in the 8-foot transonic tunnel, but not in the transonic blowdown tunnel where there is a large variation of R (fig. 3) along the model length. In order to apply the theory of reference 1 to the transonic blowdown tunnel data, it was necessary to choose a value for R. Calculations accordingly were made for two values of R arbitrarily chosen to correspond to the quarter-chord position of the model ($R = 0.074$) and to a position just rearward of the fuselage ($R = 0.125$). Reference 1 did not present for $R = 0.074$ and $b = 0.670$ the value of the quality factor k used in the correction formula. A value for k was obtained, however, by assuming that the increment in k between $R = 0.125$ and $R = 0.074$ for $b = 0.670$ was the same as the increment between these two values of R for $b = 0$.

The differences between the two corrected curves for the transonic blowdown tunnel are shown in figure 6 to be small; consequently, the boundary-induced-angle correction, according to the theory of reference 1, is in this case rather insensitive to a change in open ratio of from 0.074 to 0.125. The magnitude of the correction of reference 1 for the 8-foot transonic tunnel is also shown in figure 6 to be very small.

Quantitative verification of the theory of reference 1 cannot be accomplished by comparing the corrected lift-curve slopes of the two tunnels (fig. 6) because the differences between the uncorrected curves and also the calculated corrections are small and almost within the experimental accuracy. In addition, the data have not been corrected for blockage. On the basis of reference 7, while the blockage correction to the 8-foot transonic tunnel data appears to be negligible, a blockage correction of the same sign as for a closed tunnel would be expected for the transonic blowdown tunnel data because of the small value of R in the region of the model. Although the magnitude of the blockage correction cannot be determined from reference 7, it appears that the correction would be of no larger order of magnitude than the boundary-induced-angle correction from reference 1. Application of a blockage correction would therefore shift the C_{L_α} curves for the transonic blowdown tunnel in figure 6 to the right a small amount. Thus, although a quantitative verification of the theory of reference 1 is impossible, it does appear that application of the theory, which heretofore

has not been checked experimentally, yields a boundary-induced-angle correction of the correct sign and of the proper order of magnitude.

CONCLUSIONS

The boundary effects on an 18-inch span, 60° triangular wing model tested in the 26-inch Langley transonic blowdown tunnel are shown to cause only small decreases in the lift-curve slopes from those obtained with the same model in the Langley 8-foot transonic tunnel; the decreases amount to less than 0.001 per degree and 0.003 per degree at Mach numbers of 0.80 and 0.975, respectively. The theory of a previously published paper (NACA RM L53A26), although not exactly applicable to the present case, gave corrections to the lift-curve slopes obtained in the smaller tunnel which appeared to be of the correct sign and of the proper order of magnitude.

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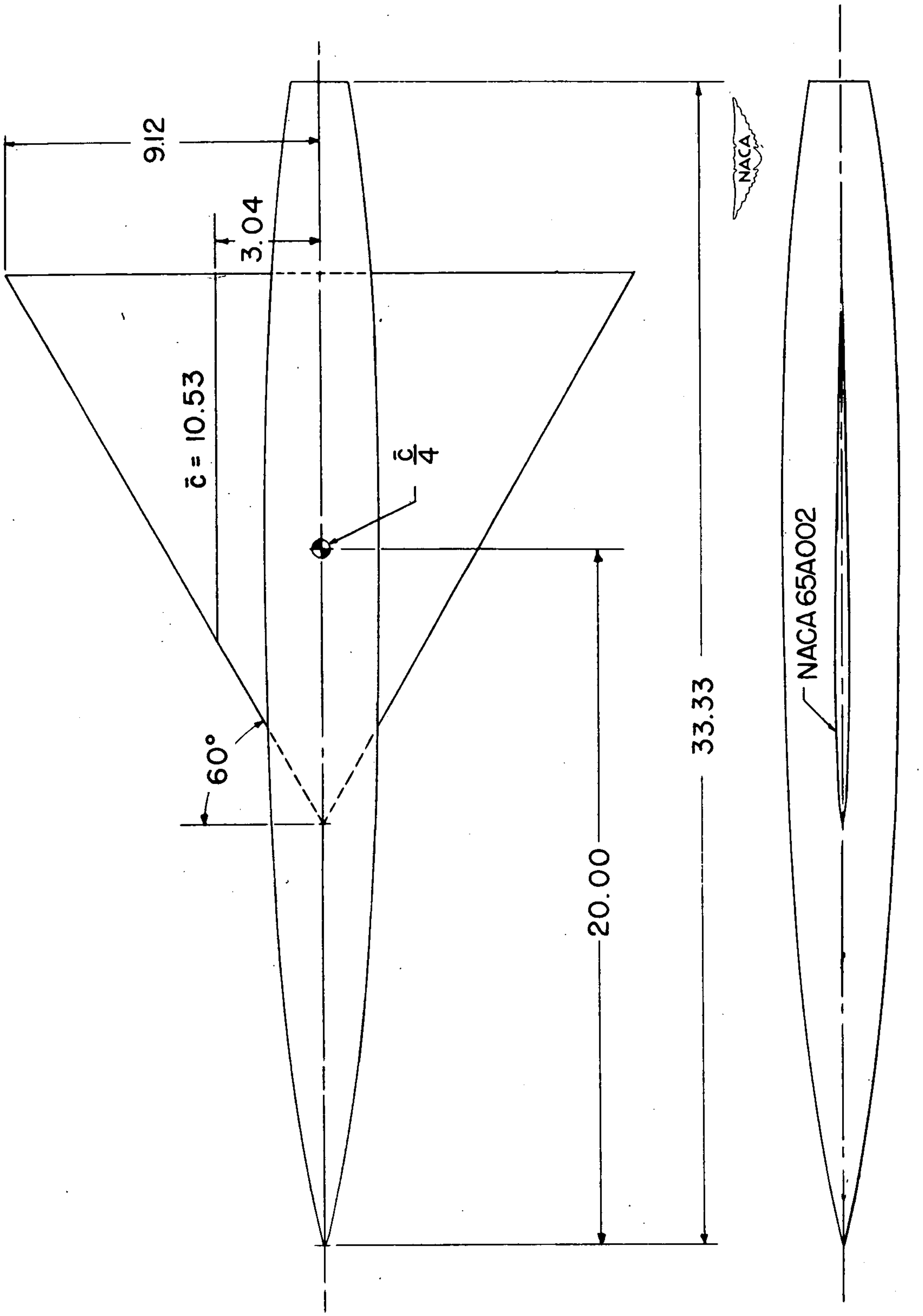
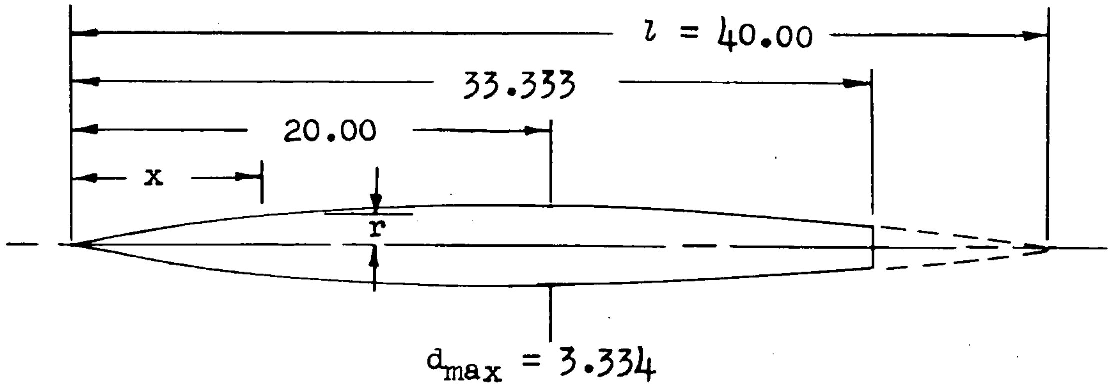


Figure 1.- Sketch of model. All dimensions are in inches.



ORDINATES			
x/l	r/l	x/l	r/l
0	0		
.0050	.00231	.4500	.04143
.0075	.00298	.5000	.04167
.0125	.00428	.5500	.04130
.0250	.00722	.6000	.04024
.0500	.01205	.6500	.03842
.0750	.01613	.7000	.03562
.1000	.01971	.7500	.03128
.1500	.02593	.8000	.02526
.2000	.03090	.8333	.02083
.2500	.03465	.8500	.01852
.3000	.03741	.9000	.01125
.3500	.03933	.9500	.00439
.4000	.04063	1.0000	0
L.E. radius = $0.0005l$			

Figure 2.- Fuselage ordinates. All dimensions are in inches.

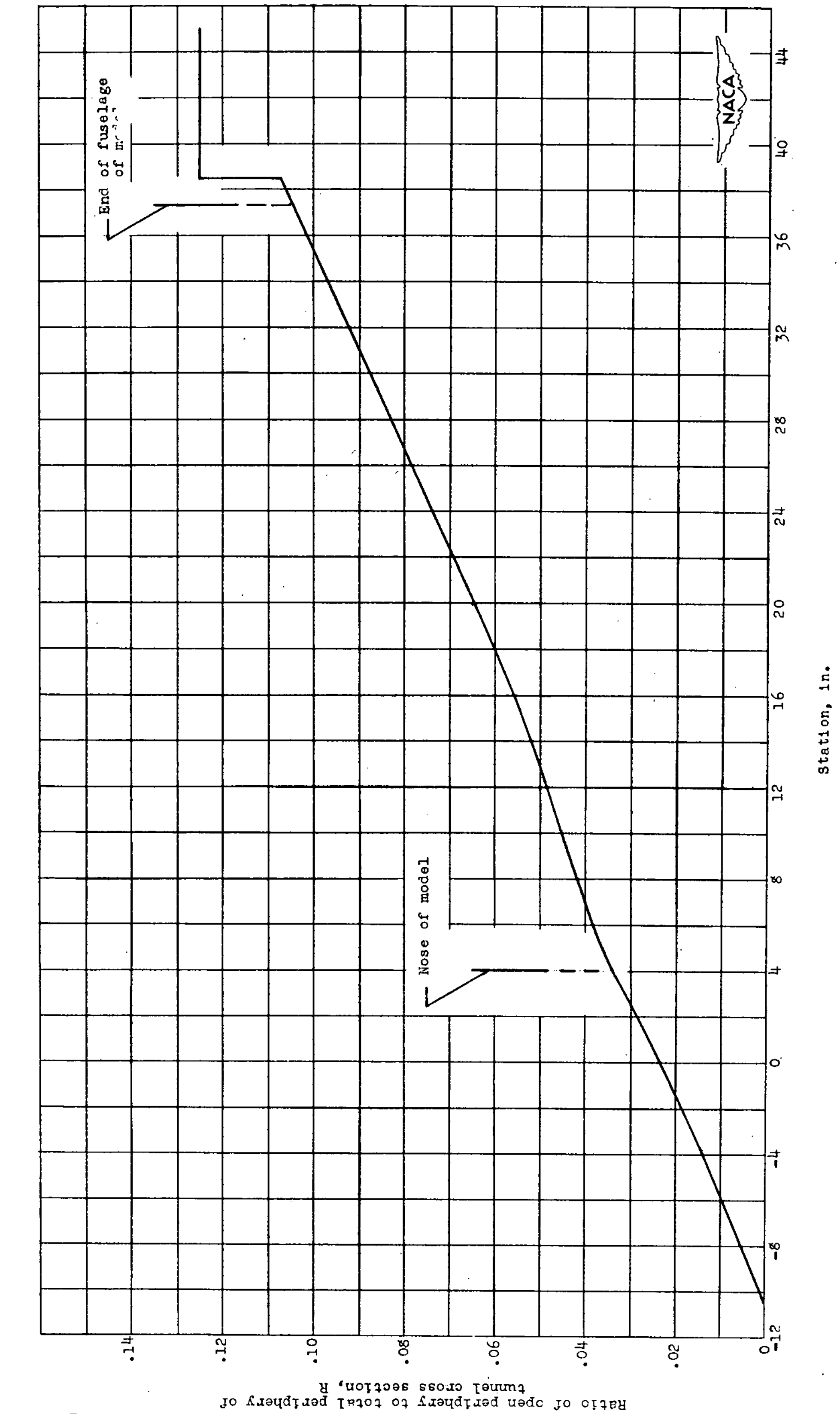


Figure 3.- Variation of R with tunnel station in Langley transonic blowdown tunnel for present tests.

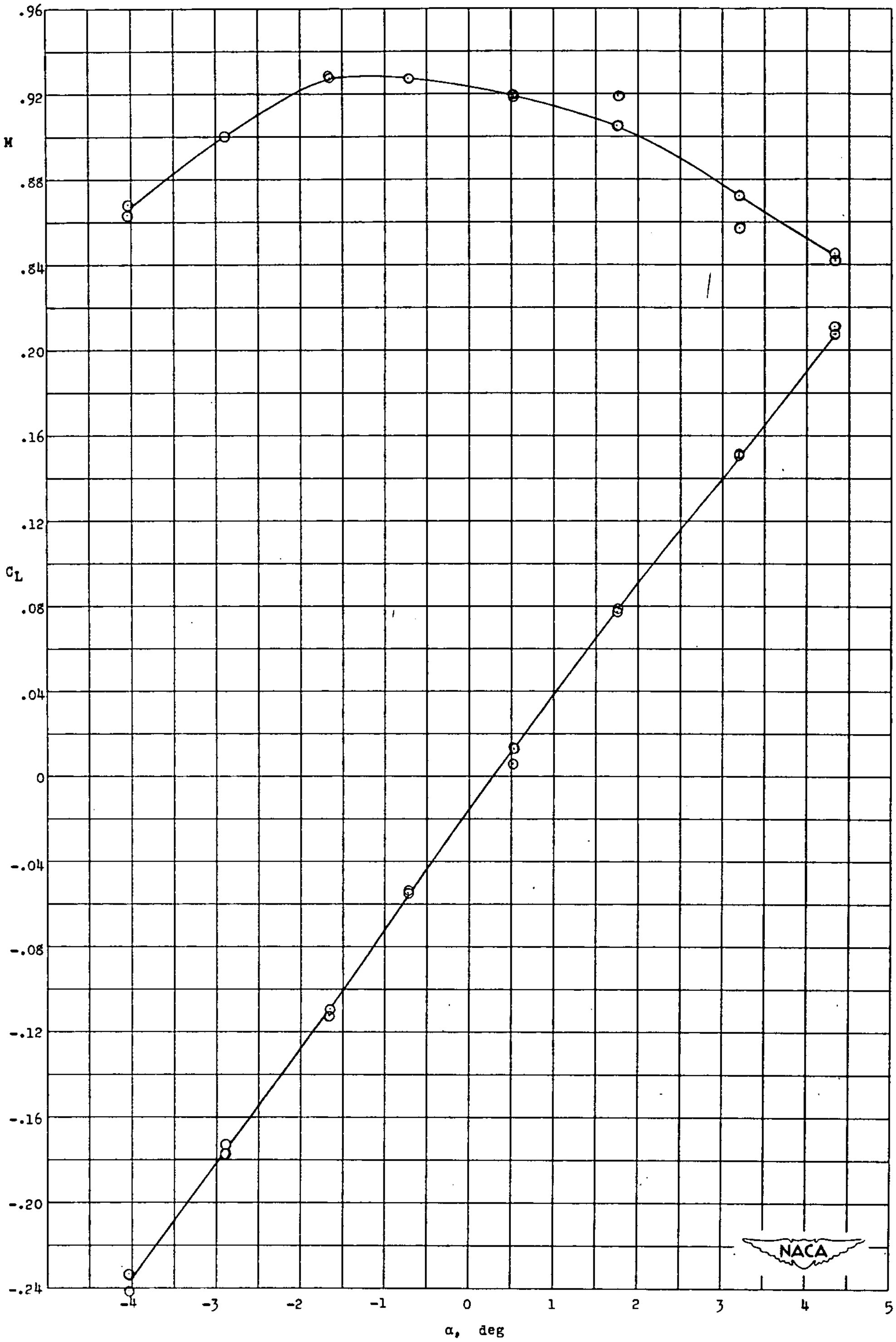


Figure 4.- Variation of Mach number and lift coefficient with angle of attack for a typical test with the present model in the Langley transonic blowdown tunnel.

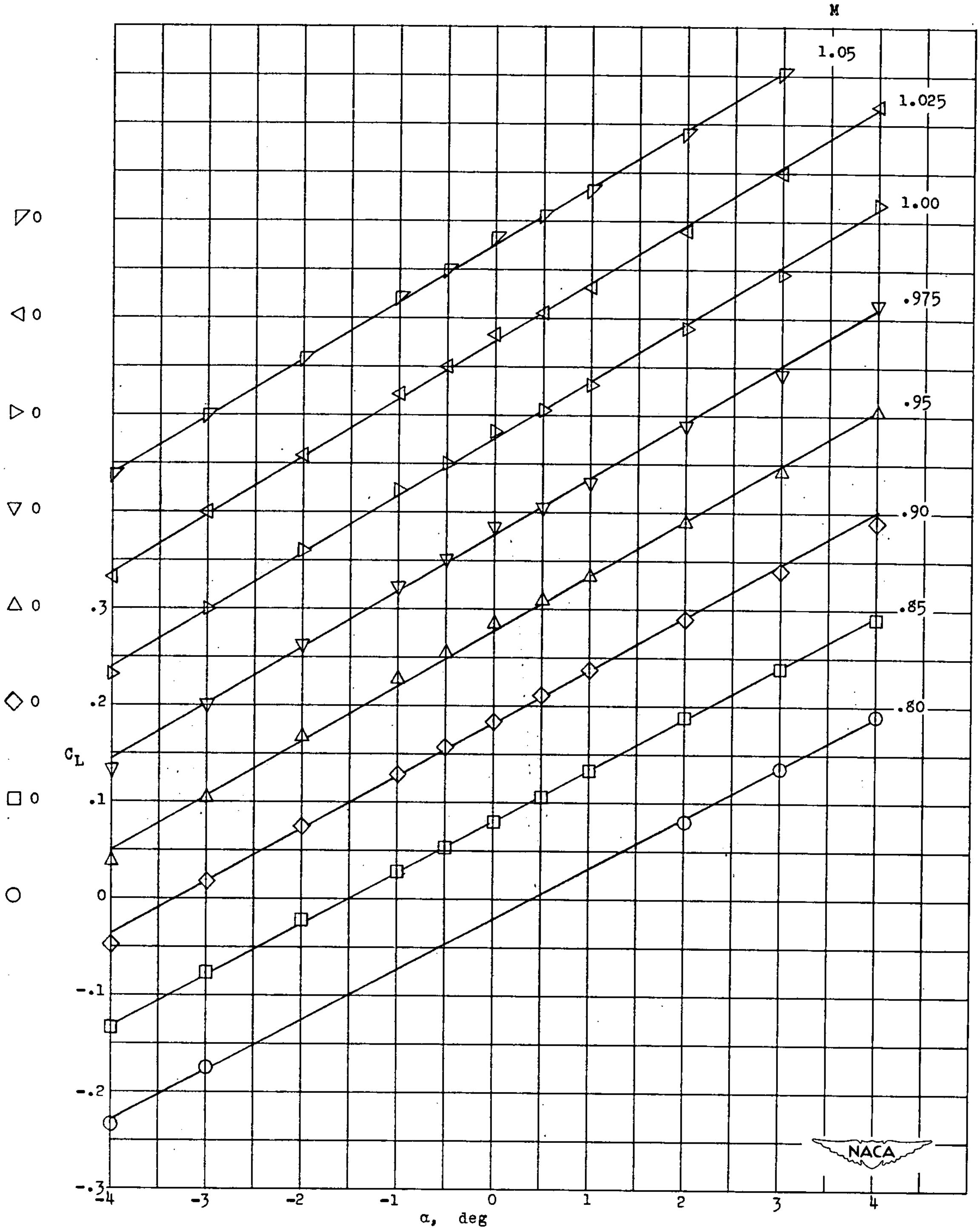


Figure 5.- Variation of lift coefficient with angle of attack for various Mach numbers from Langley transonic blowdown tunnel tests. (Symbols represent points obtained from cross plots.)

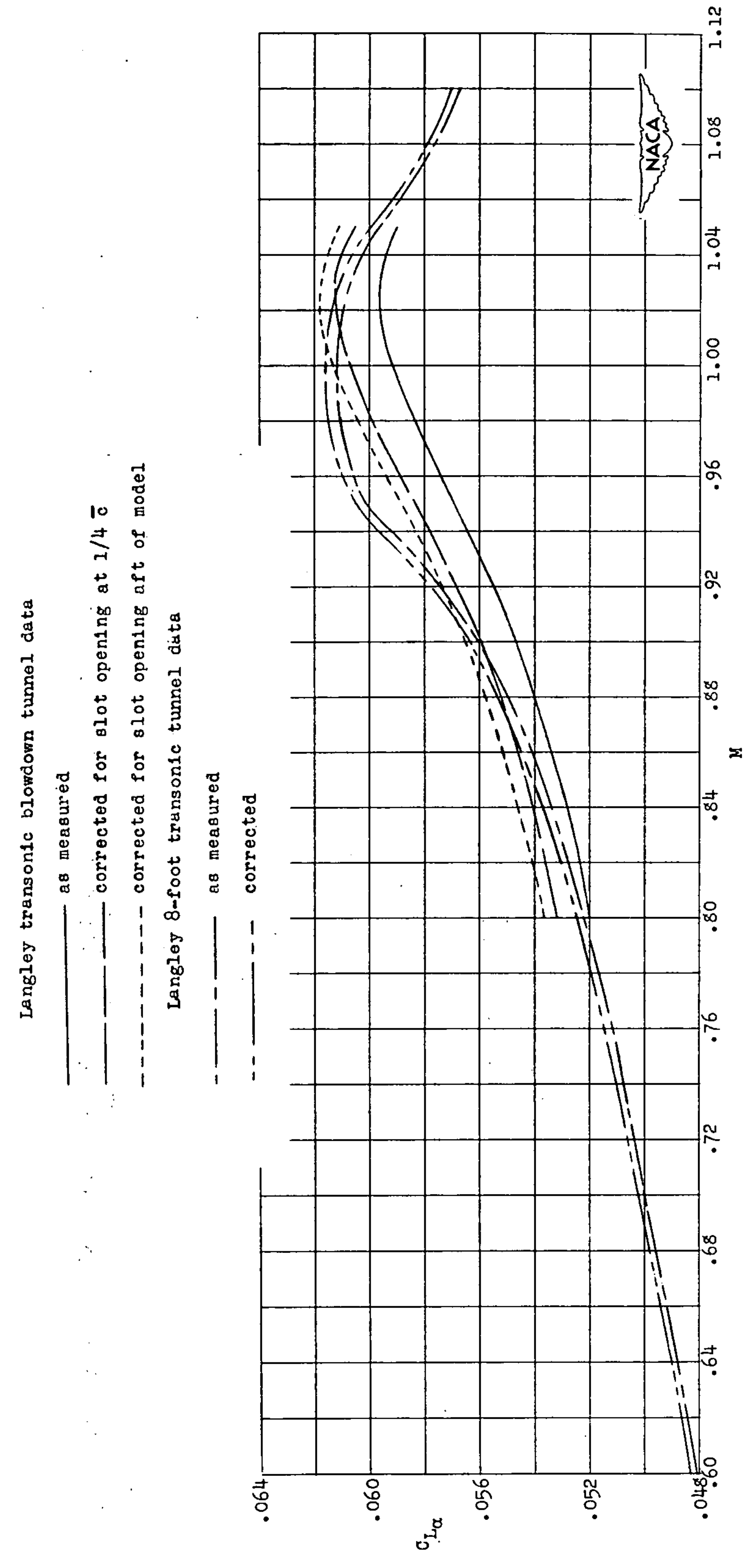


Figure 6.- Comparison of measured and calculated variations of C_{L_α} with Mach number.